

National Aeronautics and Space Administration

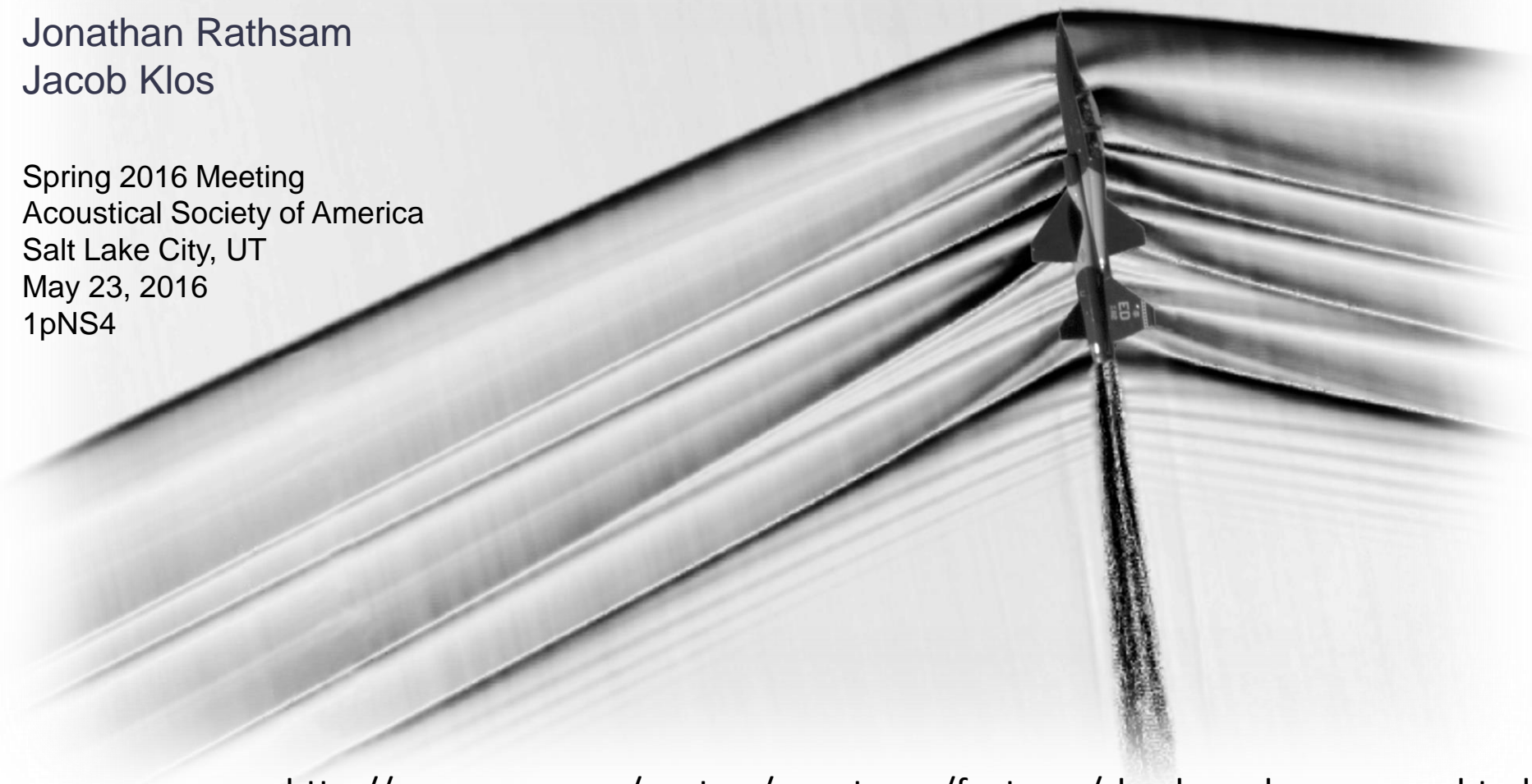


Vibration penalty estimates for indoor annoyance caused by sonic boom

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1pNS4

http://www.nasa.gov/centers/armstrong/features/shock_and_awesome.html





Acknowledgments

- NASA Commercial Supersonic Technology Project
 - Alexandra Loubeau, Jerry Rouse, Kevin Shepherd

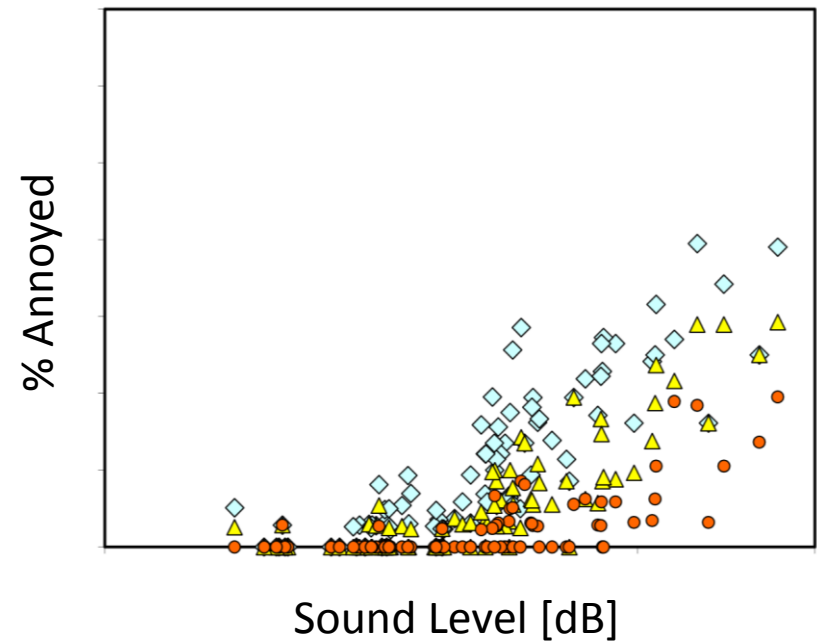


Outline

1. Motivation
2. Simulated vibration method
3. Test matrix
4. Test method
5. Results and conclusions

Motivation

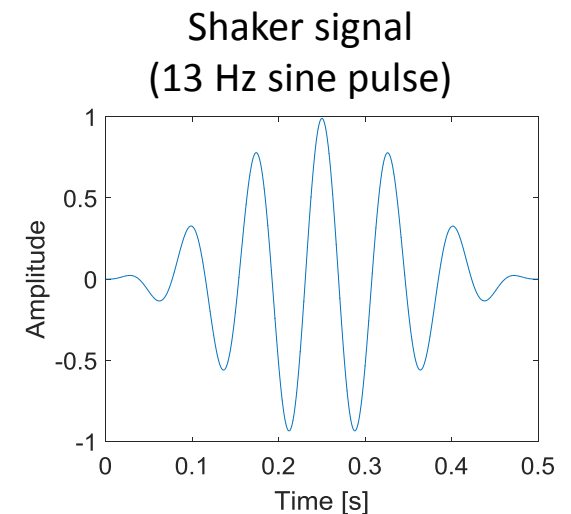
- Aircraft noise regulators (FAA, ICAO) considering allowing commercial supersonic flight
- Community annoyance prediction model
 - Link predicted booms to community annoyance
 - Support new regulations
 - Support aircraft designers



[Fidell, et al. 2012]

Laboratory Study

- Is there a vibration penalty?
 - increment in sound level that yields same annoyance increment as realistic vibration
- If so, how great?



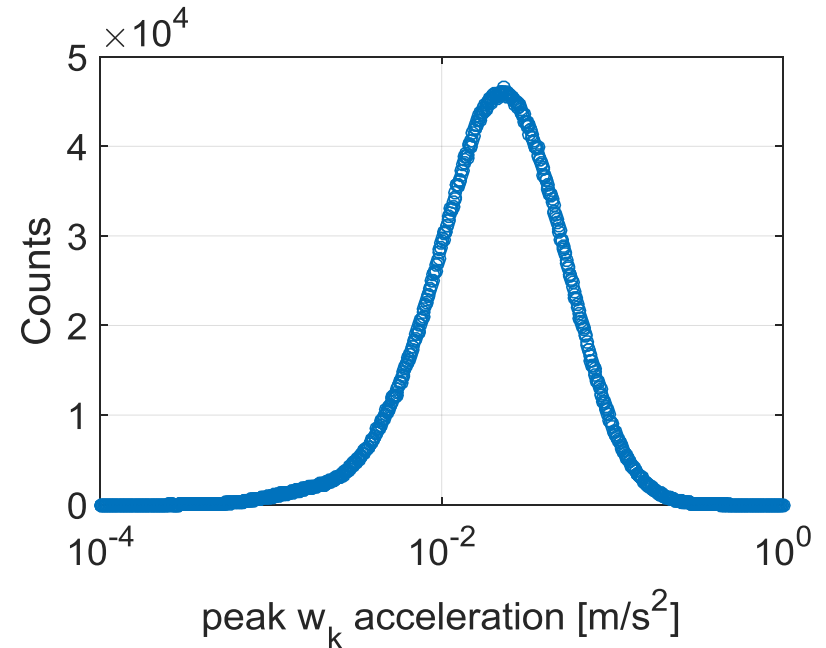


Test Matrix

Signature	Exterior PL [dB]	Peak w_k acceleration [m/s ²]	
Small Airliner	75		
Large Airliner	76		
X-plane (A)	76		
Business Jet (A)	77		
Business Jet (B)	79		
X-plane (B)	80		
X-plane (C)	84		

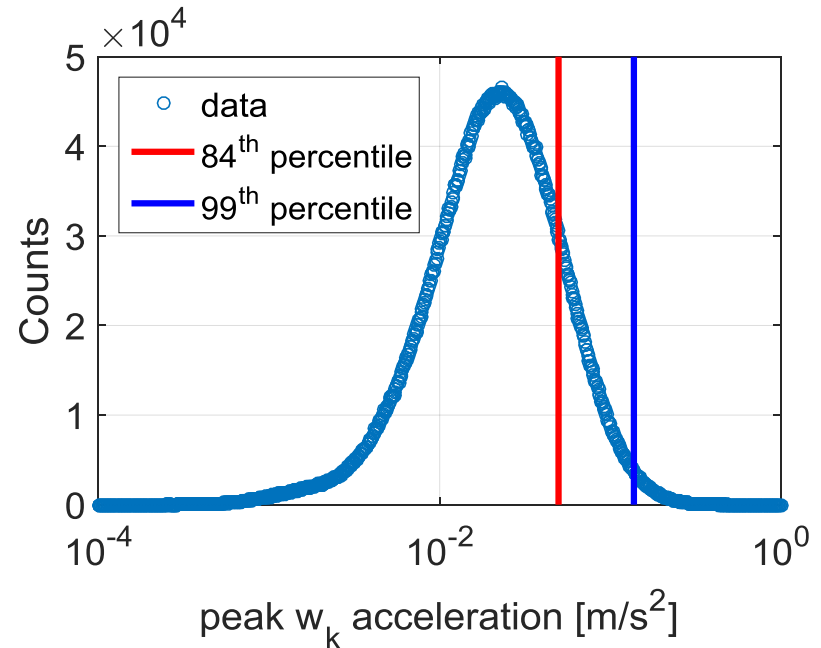
Simulated Vibration Data

- Vibration predicted across 6000 virtual buildings
- Lognormal distribution fit to data



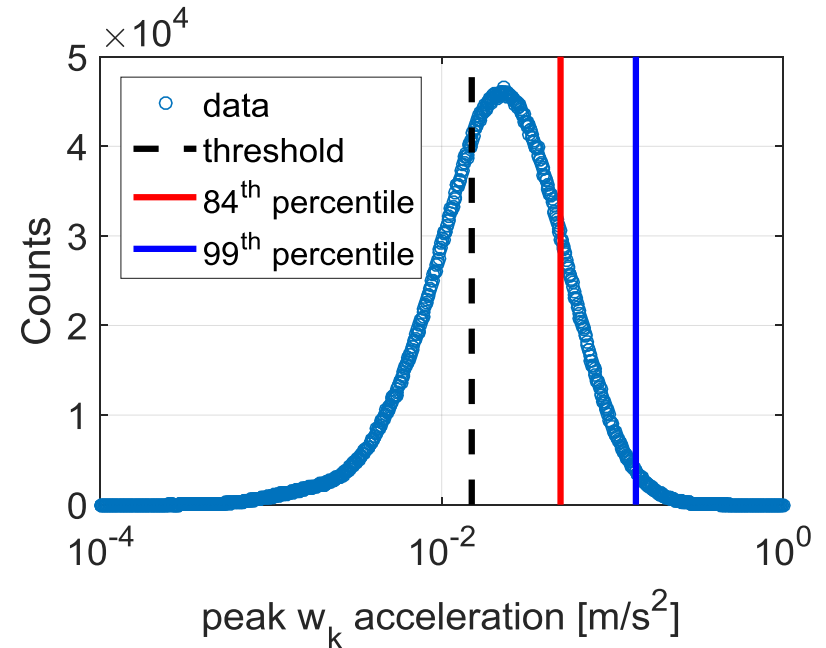
Simulated Vibration Data

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- 84th and 99th percentiles extracted for testing ($\bar{x} + \sigma$ and $\bar{x} + 3\sigma$)



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Test Matrix

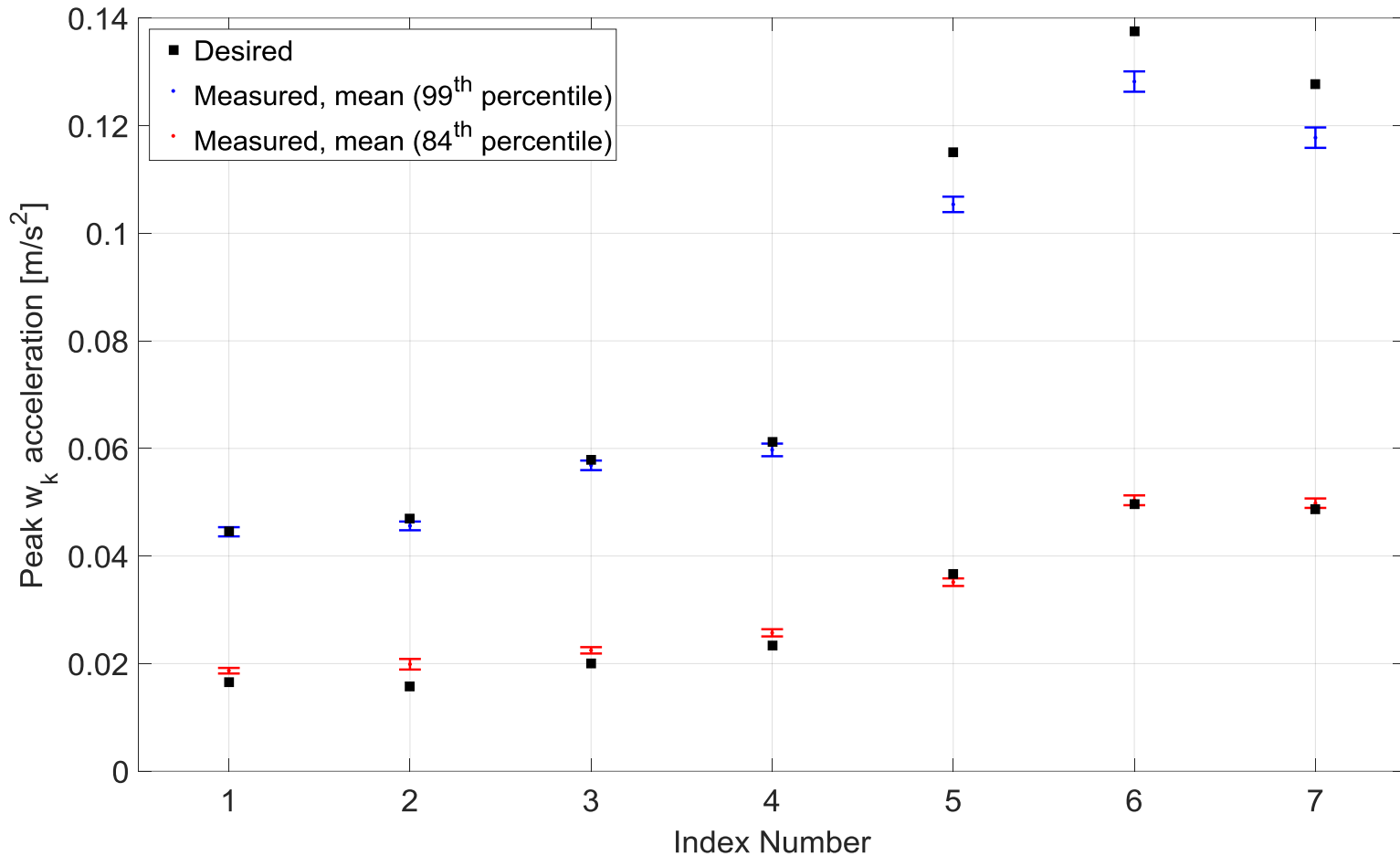
Signature	Exterior PL [dB]	Peak w_k acceleration [m/s ²]	
		84 th percentile	99 th percentile
Small Airliner	75	0.017	0.045
Large Airliner	76	0.016	0.047
X-plane (A)	76	0.020	0.058
Business Jet (A)	77	0.023	0.061
Business Jet (B)	79	0.037	0.115
X-plane (B)	80	0.050	0.138
X-plane (C)	84	0.050	0.128



Comparison with Previous Lab Research

	Acoustics		Vibration		
	Frequency (Hz)	Level	Frequency (Hz)	Level (m/s ²)	Level (VDV) m/(s ^{1.75})
Current Study (Quiet Sonic Booms)	1 – 2000 (impulsive, peak ~10 Hz)	61 – 69 (dB, ASEL)	13 Hz (impulsive)	0.02 – 0.16	0.008 – 0.065
Leatherwood 1979 (Aircraft Cabin Noise)	63 – 2000 (octave band noise)	76 – 94 (dBA, SPL)	3,6,9,12 Hz	1.04 – 3.14 (at 12 Hz)	/
Howarth and Griffin 1991 (Railway noise)	20 – 3000 (pink noise)	52.5 – 77 (dB, ASEL)	10 – 60 Hz	/	

Measured Chair Acceleration



Error bars indicate standard error of the mean

Test Method

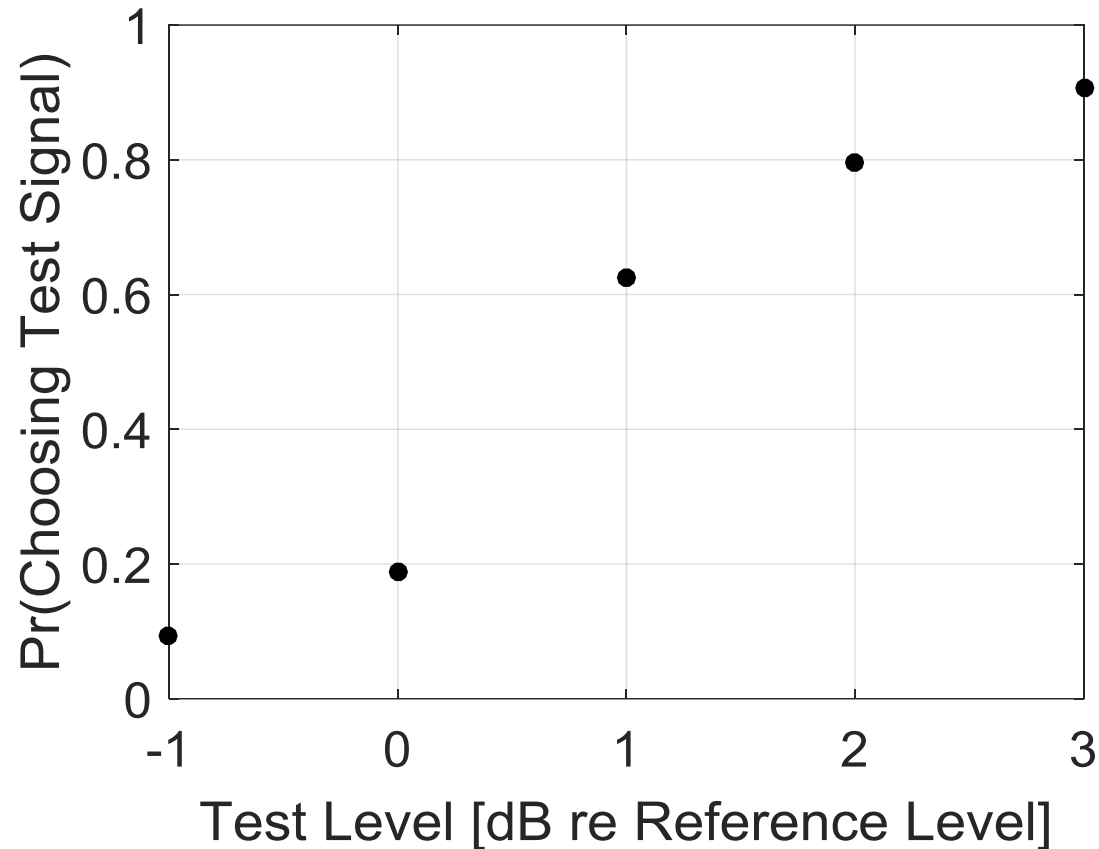
First

Second

Which event is more annoying?

Reference contains sound *and* vibration

Test contains sound alone



Test Method

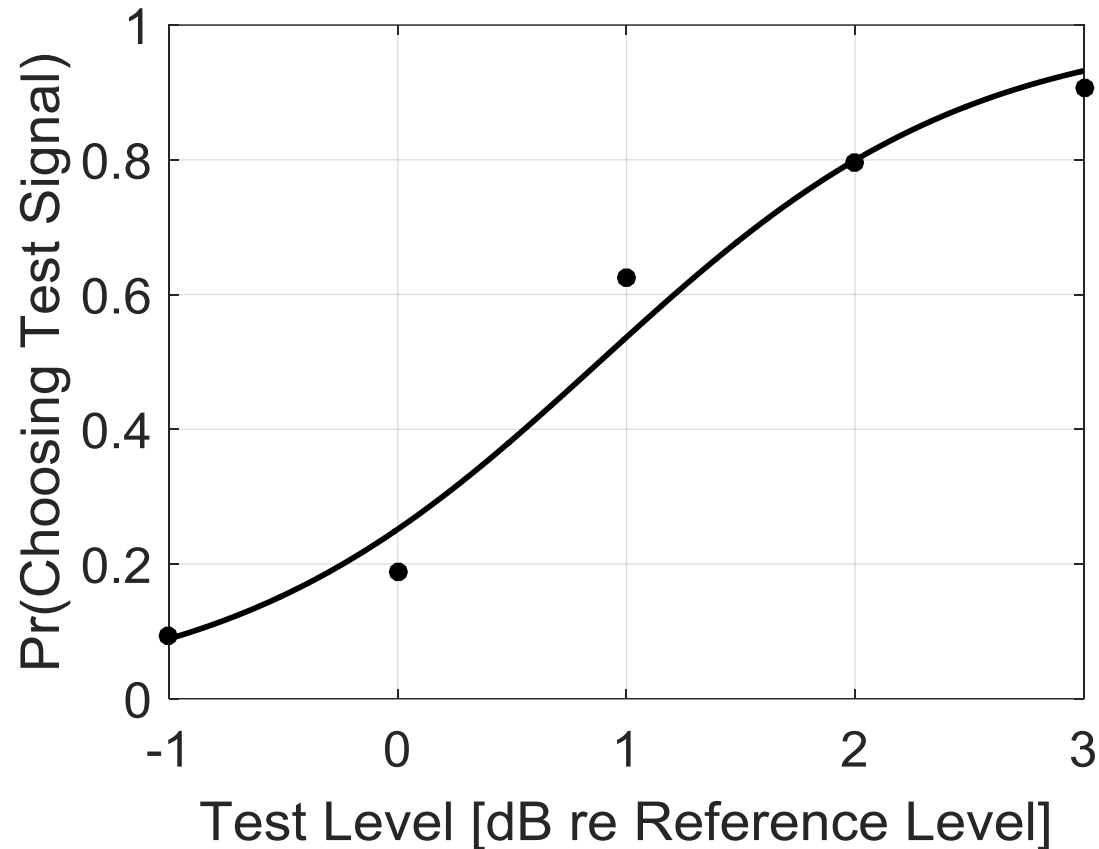
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Test Method

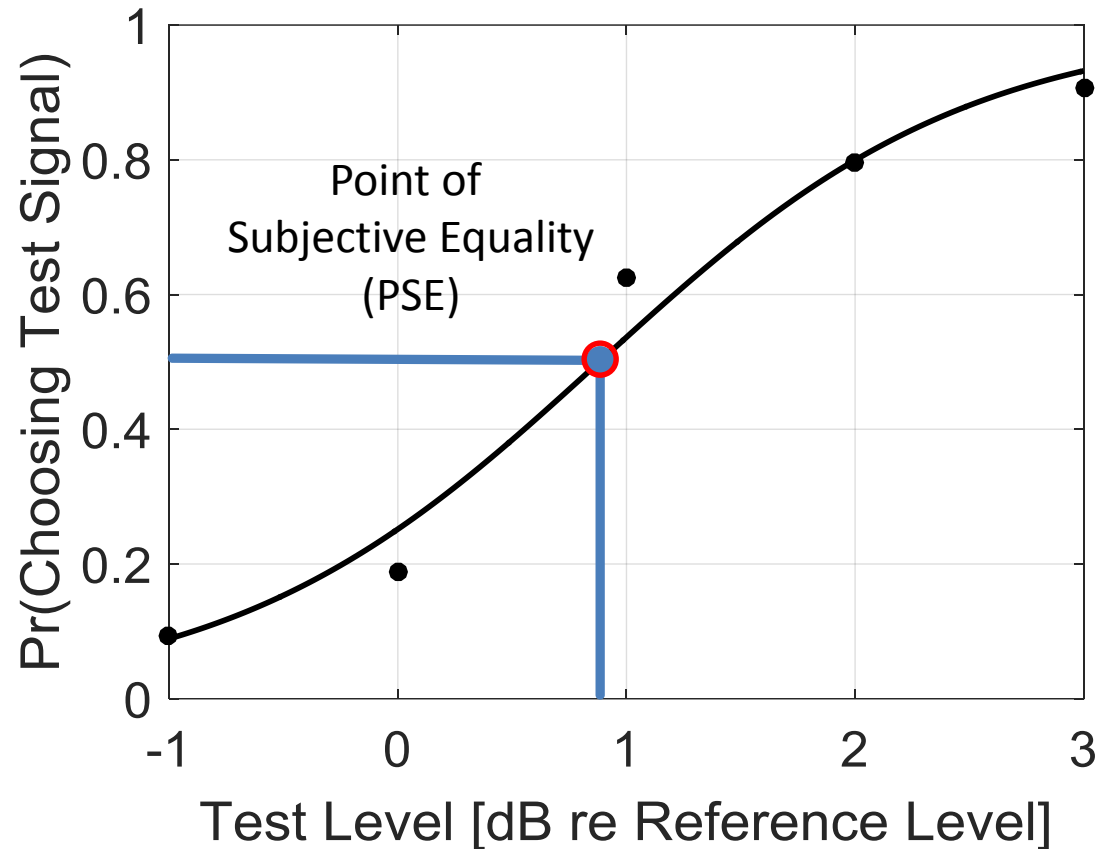
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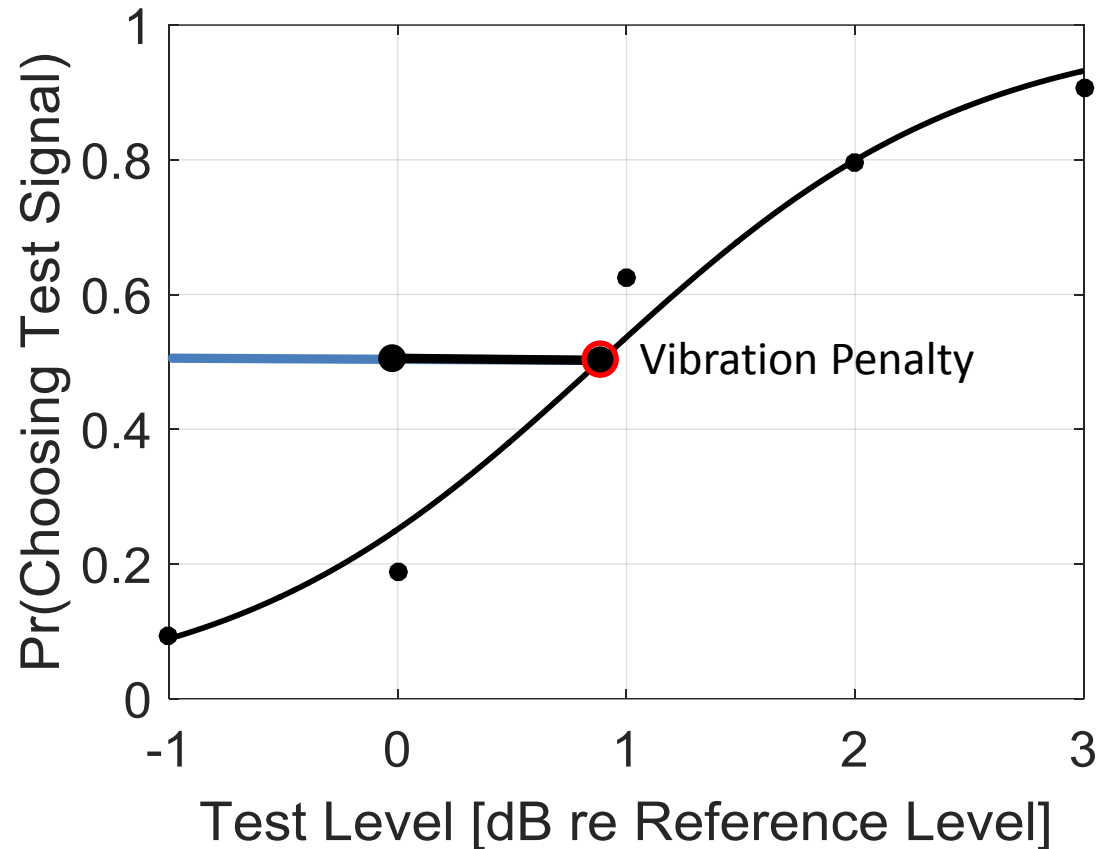
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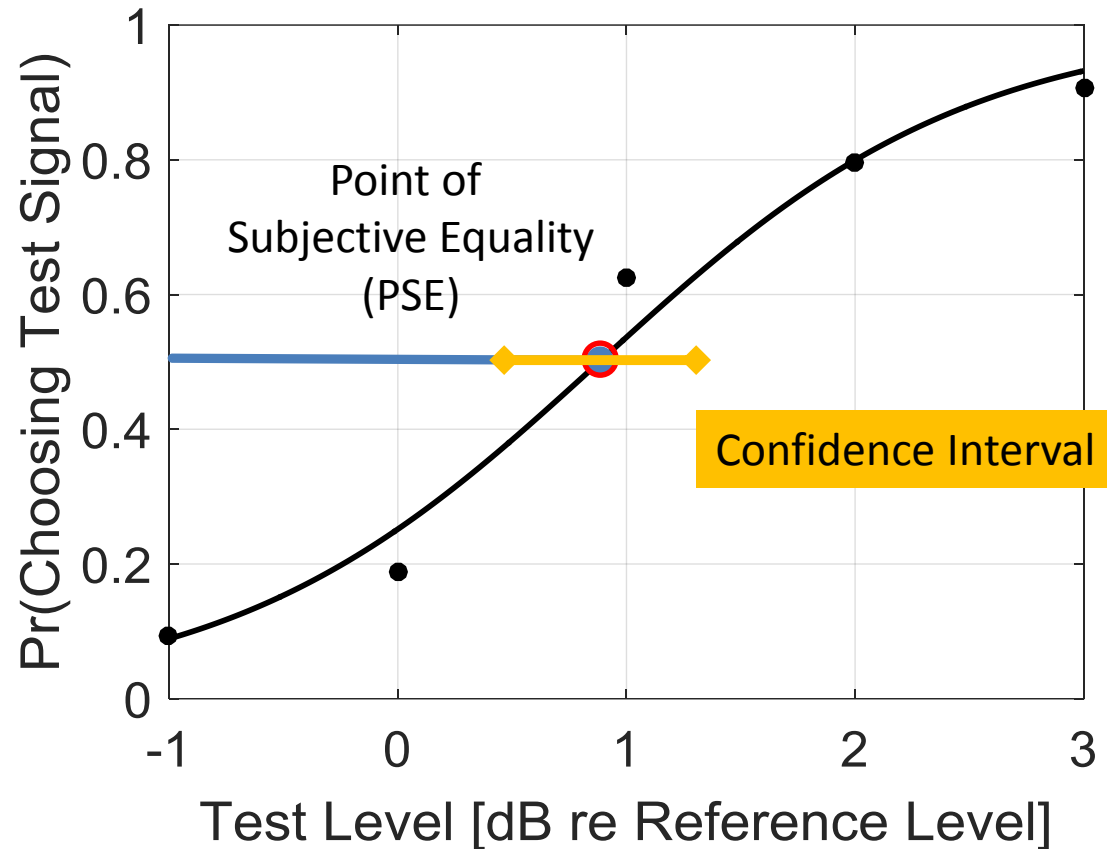
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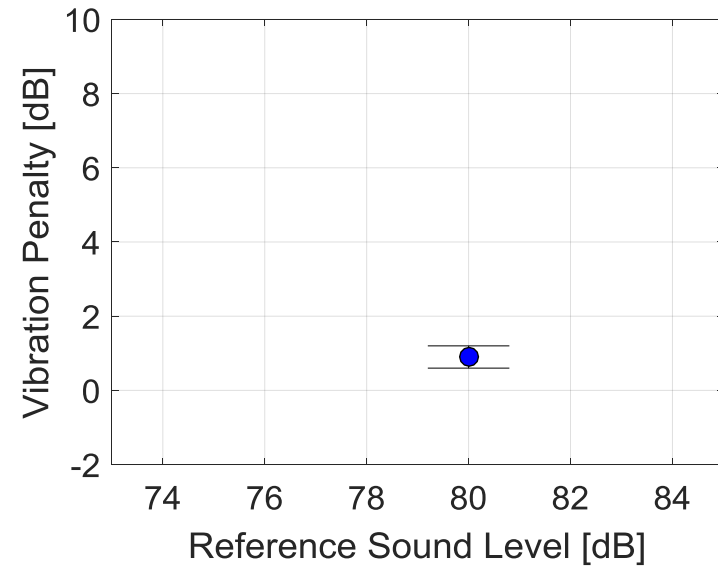
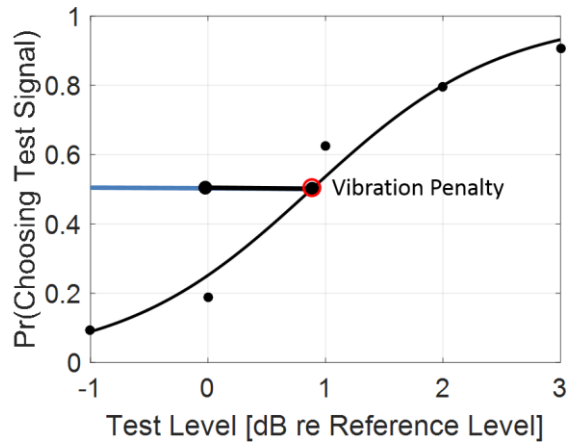
Test contains sound alone



Research Question Revisited

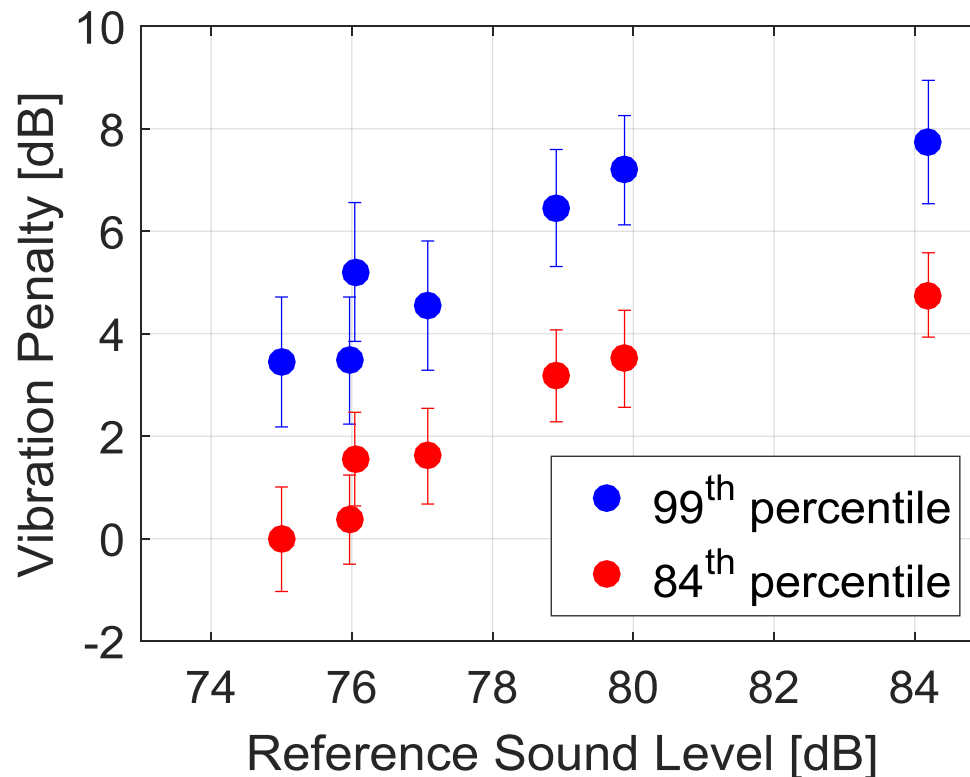
First Second

Which event is more annoying?



Research Question Revisited

- Is there a vibration penalty? Yes
0 – 5 dB for lower vibration and 4 – 8 dB for higher vibration





Thank You

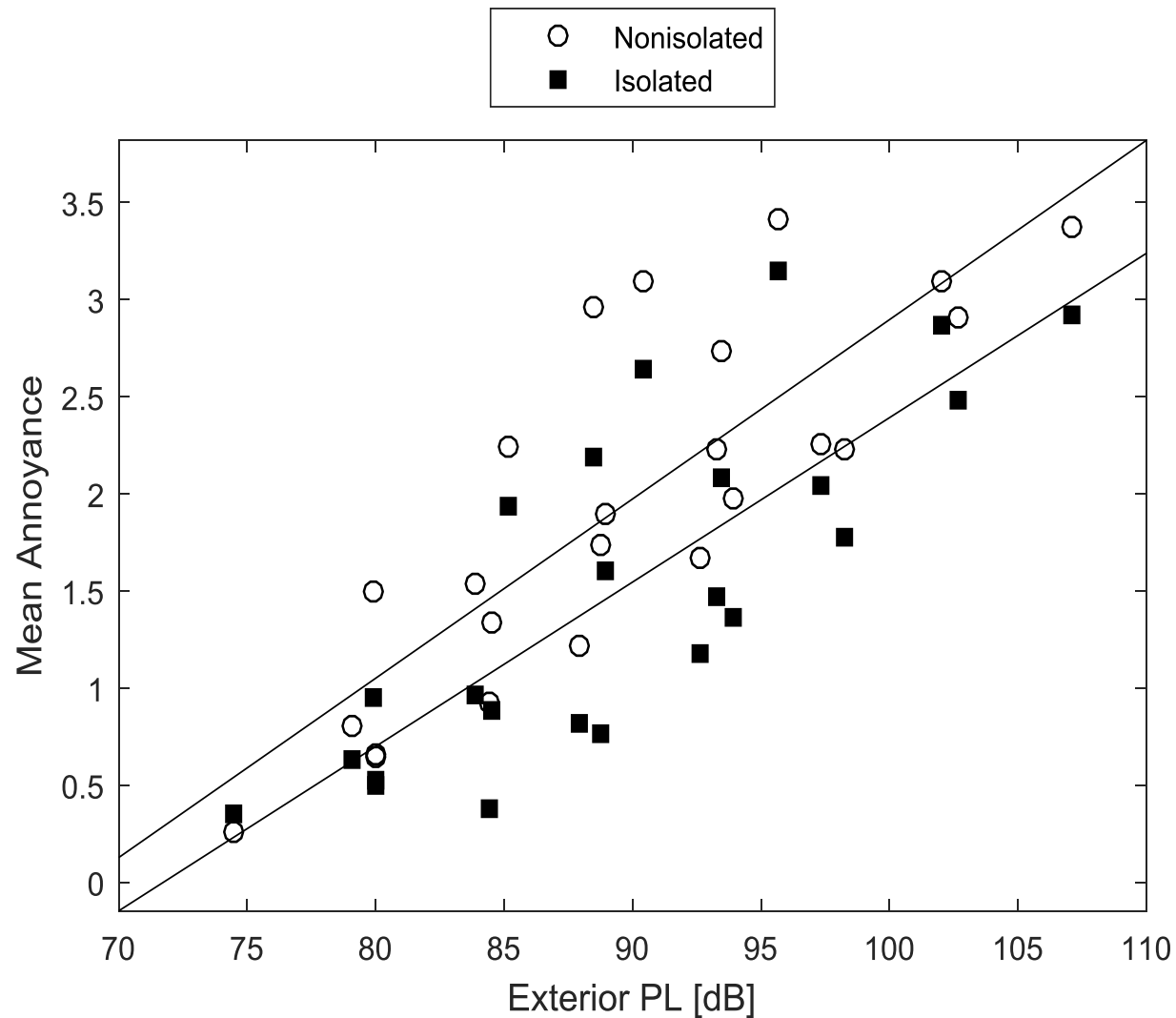
References:

- Fidell, S. et al. "Pilot Test of a Novel Method for Assessing Community Response to Low-Amplitude Sonic Booms" NASA/CR-2012-217767 (2012).
- Henne, P.A. "Case for Small Supersonic Civil Aircraft" *Journal of Aircraft* 42 (3) 765-774 (2005).
- Howarth, H.V.C. and M.J. Griffin, "The annoyance caused by simultaneous noise and vibration from railways," *J. Acoust. Soc. Am.*, 89(5), 2317-2323, (1991).
- Leatherwood, J.D. "Human Discomfort Response to Noise Combined with Vertical Vibration," NASA Technical Paper 1374 (1979).



Backup Slides

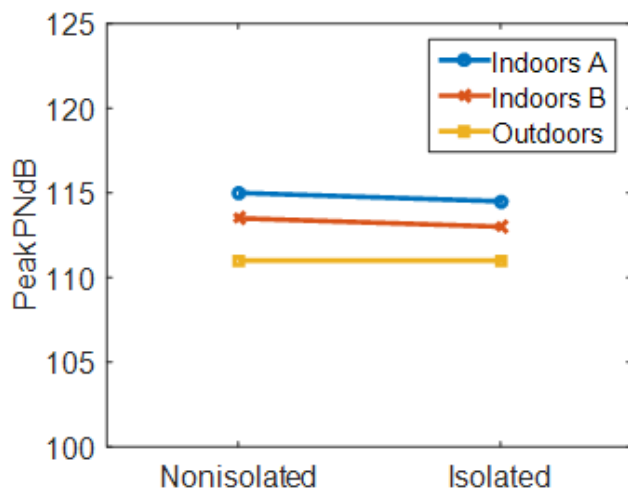
Motivation (2 of 2)



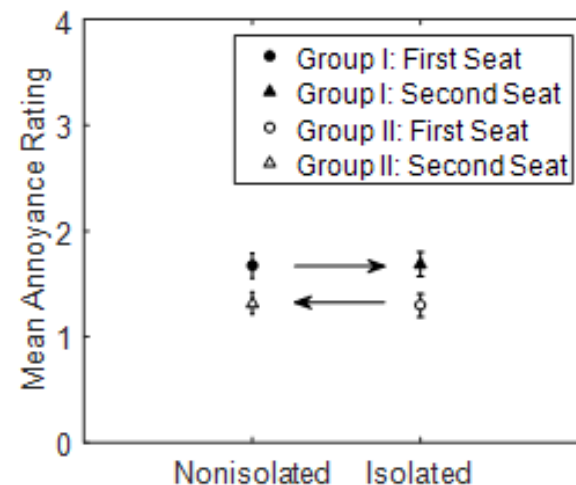
Are vibrations from a sonic boom annoying?



- “...sonic booms experienced inside were less acceptable than those experienced outside presumably because of ...the rattling and shaking of items within the structure, and the *actual vibration of the structure itself*.”
[Nixon and Borsky 1966]



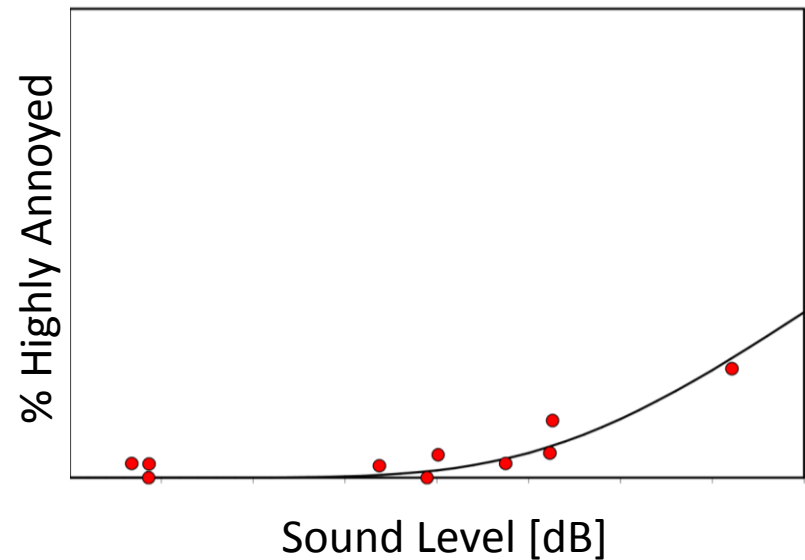
Kryter, et al. 1968



Rathsam, et al. 2014

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Fidell, et al. 2012

Measured Acceleration

